AcuTarget Measurements: Repeatability and Comparison to OPD-Scan III

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ABSTRACT

PURPOSE: To evaluate repeatability of the AcuTarget (SensoMotoric Instruments, Teltow, Germany) measurements and compare them to those obtained with the OPD-Scan III (NIDEK, Inc., Fremont, CA).

METHODS: Measurements were taken with the AcuTarget and OPD-Scan III in 62 eyes of 31 patients. Results were compared using paired Student's *t* tests, Pearson correlation coefficients, and 95% limits of agreement.

RESULTS: Repeatability of the AcuTarget was good with intraclass correlation coefficients of 0.773, 0.777, and 0.780 for Purkinje-versus-pupil along the x-axis, y-axis, and chord length measurements, respectively. No statistically significant difference was observed between the AcuTarget and OPD-Scan III for Purkinje-versus-pupil measurement along the x-axis (P = .061) and chord length (P = .950). Conversely, a statistically significant difference was observed between the two systems for measurements along the y-axis (P < .001). No statistical difference was found between the mean of the first three acquisitions and the best acquisition obtained with the AcuTarget.

CONCLUSIONS: Measurements provided by the AcuTarget have good repeatability and are close to those obtained with the OPD-Scan III. Although controversies remain on where to best center refractive procedures, this may help in analyzing the importance of refractive surgery centration in relation to visual acuity and visual symptoms.

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Remarkable axes of the eye are due to one of its peculiarities: lack of a common axis for main refractive structures (ie, cornea and lens). In addition, the fovea is slightly temporal to the emergence of the optic nerve. Some axes have a functional value (eg, visual axis or line of sight), whereas others have a primarily anatomical value (eg, pupil axis). The angle kappa is between the pupil and visual axes, whereas the angle lambda is between the pupil axis and line of sight.[1,2] Both angles are nearly identical if the point of fixation is not close to the eye (**Figure 1**).[2]

Where to center corneal refractive procedures to maximize visual outcomes remains controversial.[3] An improperly centered treatment may result in undercorrection or other undesirable side effects. The pupil center is often a reference for refractive procedures. However, corneal light reflex may be better because it may lie nearer to the corneal intercept of the visual axis than the pupil center.[4-8] Furthermore, compensation for angle kappa is important for optimal correction of refractive error by either laser ablation or intraocular lenses, especially for hyperopes and any eyes with large angle kappa.[2]

The AcuTarget (SensoMotoric Instruments, Teltow, Germany) is new and helps identify both the corneal vertex and pupil center. It can be used to guide surgeons on proper surgical placement of intracorneal small aperture inlays, which are new treatment options for presbyopia. It can also be used for cataract surgery to determine precise placement of a toric intraocular lens.

The purpose of this study was to assess repeatability of the AcuTarget measurements and compare them to those obtained with the OPD-Scan III (NIDEK, Inc., Fremont, CA).

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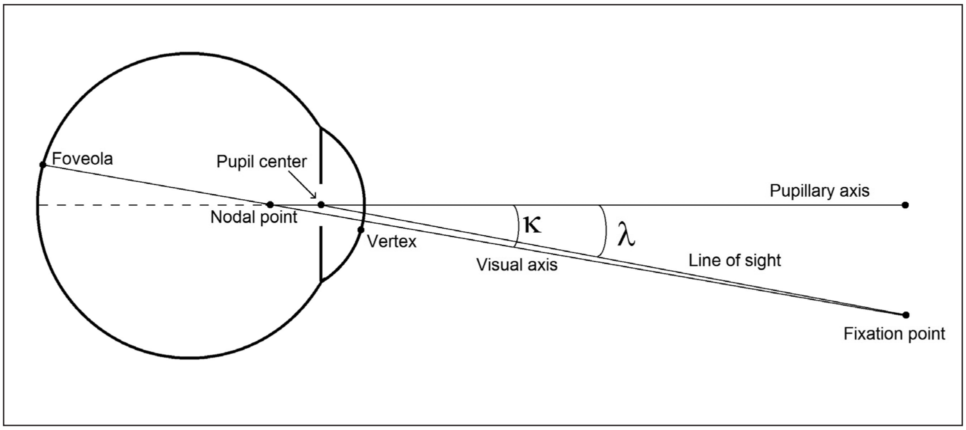

Figure 1. Angles of the eye. The pupillary axis is the line that joins the center of the entrance pupil to a point at the anterior corneal surface (where the local tangent is perpendicular). The visual axis is the (broken) line joining the fixation point to the first nodal point and the second nodal point to the fovea. Given the proximity of the nodal points, the posterior nodal point can be considered a unique nodal point for simplicity. The line of sight joins the pupil center to the fixation point. The angle kappa is between the pupil and visual axes. The angle lambda is between the pupil axis and line of sight. In practice, the values of angle kappa and angle lambda are very close.

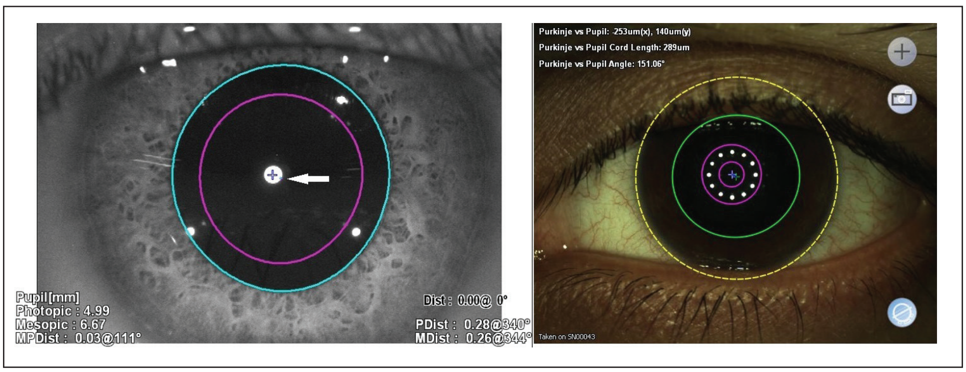

Figure 2. Purkinje-versus-pupil measurement with the OPD-Scan III (NIDEK, Inc., Fremont, CA) (left) and AcuTarget (SensoMotoric Instruments, Teltow, Germany) (right). With the OPD-Scan III, the vertex is identified by a white cross and the center of the pupil in mesopic condition is marked by a green cross (white arrow). The AcuTarget is marked with the same identifiers. The distance between the vertex and pupil center is then calculated.

PATIENTS AND METHODS

Patients were prospectively recruited from the Department of Refractive Surgery at the Rothschild Ophthalmic Foundation, Paris, France. Exclusion criteria were previous ocular surgery or ocular pathology other than refractive error. The local ethics committee approved this study, which followed the tenets of the Declaration of Helsinki.

Contact lens wearers were asked not to wear lenses for 72 hours before measurements were taken. Patients had a subjective refraction and then measurements were taken with the AcuTarget and OPD-Scan III. Measurements were taken at the same time of day (between 10 AM and 6 PM) and acquisitions were made under similar mesopic conditions. Both eyes of each patient were used for statistical analysis because eyes were not compared to one another.

Illuminance in the examination rooms was measured with a Topcon BM-3 luminance meter (Topcon Corporation, Tokyo, Japan). It was 2.5 and 3.1 lux, respectively, in the rooms where the AcuTarget and OPD-Scan III were located.

CORNEAL TOPOGRAPHY

Examinations started with the OPD-Scan III. The patient's chin was placed on the chin rest and the forehead was pressed against the forehead strap. The eye was then aligned with the visual axis by a central fixation light. The examiner sees a real-time image of the eye on the screen. Two acquisitions are necessary for each eye. When the image is focused and centered, the software automatically measures. Placido topography is then performed. In each case, the patient was asked to remain still and keep his or her eyes open. A trained operator performed the examinations.

ACUTARGET MEASUREMENTS

Before each use, the system was calibrated as recommended by the manufacturer and patients were asked to look at a central fixation light. Five acquisitions were necessary for each measurement and the system automatically chose the best one. For each eye, three successive measurements were taken (15 acquisitions) and all acquisitions were saved using the screenshot feature (**Figure 2**). The same operator performed all AcuTarget measurements.

STATISTICAL ANALYSIS

For each Purkinje-versus-pupil measurement, the pupil center was used as the origin. The value was positive along the x-axis if the vertex was temporal to the pupil center and negative if the vertex was nasal to the pupil center.

The main outcome measure was the repeatability of the AcuTarget measurements (distance between pupil center and Purkinje reflex [x-axis, y-axis, and chord

TABLE 1
Mean AcuTarget and OPD-Scan III Readings and Subjective Refraction

Method	Mean ± SD	Range	95% CI
Subjective refraction			
Sphere (D)	-2.43 ± 3.74	-7.75 to 8.75	-3.38 to -1.48
Cylinder (D)	-0.73 ± 0.78	-3.75 to 0.00	-0.93 to -0.54
AcuTarget[a]			
PvP along the X-axis (μm)	-264.44 ± 170.46	-619.33 to 110.67	-307.73 to -221.15
PvP along the Y-axis (μm)	153.49 ± 164.35	-349.67 to 742.67	111.76 to 195.23
PvP chord length (μm)	357.01 ± 164.58	80.33 to 950.67	315.22 to 398.81
OPD-Scan III			
Sphere (D)	-2.68 ± 3.36	-8.00 to 6.75	-3.53 to -1.82
Cylinder (D)	-0.71 ± 0.70	-3.50 to 0.00	-0.88 to -0.53
PvP along the X-axis (μm)	-292.29 ± 207.26	-882.95 to 229.97	-345.37 to -239.21
PvP along the Y-axis (μm)	41.90 ± 169.02	-358.71 to 779.88	-1.39 to 85.19
PvP chord length (μm)	352.79 ± 183.39	60 to 1000	305.82 to 399.75

SD = standard deviation; CI = confidence interval; D = diopters; PvP = Purkinje-versus-pupil measurement
[a]Mean of the three measurements.
The AcuTarget is manufactured by SensoMotoric Instruments, Teltow, Germany, and the OPD-Scan III is manufactured by NIDEK, Inc., Fremont, CA.

length]). The measurements were then compared to those obtained with the OPD-Scan III. AcuTarget measurements were also compared to the mean of its first three acquisitions.

Repeatability was assessed using intraclass correlation coefficients. Differences between the systems were assessed using the paired Student's *t* test. Pearson correlation coefficients were used to show data correlation. The Bland-Altman method was used to assess agreement in variables between the two systems and 95% limits of agreement were calculated. Data are presented as the mean ± standard deviation. As multiple comparisons were made, the significance level was corrected for the total number of comparisons using the Bonferroni method.[9,10] A calculated *P* value of less than .0035 was considered statistically significant. All data were analyzed using SPSS software (version 20; SPSS, Inc., Chicago, IL).

RESULTS

Sixty-two eyes of 31 patients (15 men and 16 women) were included. The mean age was 31.2 ± 7.4 years (range: 22 to 54 years). **Table 1** shows data obtained with the AcuTarget and OPD-Scan III.

Repeatability

Agreement of three successive measurements performed during the same visit was good for AcuTarget readings with intraclass correlation coefficients greater than 0.75. Calculated intraclass correlation coefficient was 0.773 for Purkinje-versus-pupil measurement along the x-axis, 0.777 for the y-axis, and 0.780 for chord length.

Comparison Between the AcuTarget and OPD-Scan III

Table 2 shows the comparison between data obtained with the two systems and subjective refraction.

Purkinje-versus-pupil measurements along the x-axis obtained with the AcuTarget and OPD-Scan III under mesopic conditions were not significantly different and were strongly correlated. Furthermore, comparison of chord length measurements also showed no significant difference and a good correlation. Conversely, a statistically significant difference between the two systems was observed for y-axis measurements (**Figure 3**).

Refraction (sphere and cylinder) measurements obtained with the OPD-Scan III were highly correlated to subjective refraction; sphere measurements were significantly different from those obtained with subjective refraction (with values slightly more negative on the former), whereas cylinder readings were not significantly different between the two.

Comparison Between the Mean of the First Three Acquisitions and the Best Acquisition Obtained With AcuTarget

Table 3 shows the comparison between the mean of the first three acquisitions and the best acquisition obtained with the AcuTarget. Data were highly correlated with Pearson correlation coefficients ranging from 0.967 to 0.984. No statistically significant difference could be found between the first three and best acquisitions.

TABLE 2
Comparison Between Data Obtained With the AcuTarget and OPD-Scan III and Subjective Refraction

	Difference of Mean (A-B)		Pearson Correlation		95% LoA	
Parameter (A vs B)	**Δ ± SD**	***P***	***r***	***P*[a]**	**Lower**	**Upper**
Refraction						
Subjective versus OPD-Scan III (sphere) (D)	0.25 ± 0.58	.001	0.992	< .001	-0.89	1.39
Subjective versus OPD-Scan III (cylinder) (D)	-0.03 ± 0.29	.452	0.926	< .001	-0.60	0.54
Purkinje-versus-pupil distance						
AcuTarget versus OPD-Scan III (X-axis) (µm)	31.93 ± 130.46	.061	0.778	< .001	-223.77	287.63
AcuTarget versus OPD-Scan III (Y-axis) (µm)	111.70 ± 181.93	< 0.001	0.409	.001	-244.88	468.28
AcuTarget versus OPD-Scan III (chord length) (µm)	1.19 ± 146.04	.950	0.652	< .001	-285.05	287.43

LoA = limits of agreement; Δ = change; D = diopters
[a]A calculated P value of less than .0035 (using Bonferroni method) was considered statistically significant.
The AcuTarget is manufactured by SensoMotoric Instruments, Teltow, Germany, and the OPD-Scan III is manufactured by NIDEK, Inc., Fremont, CA.

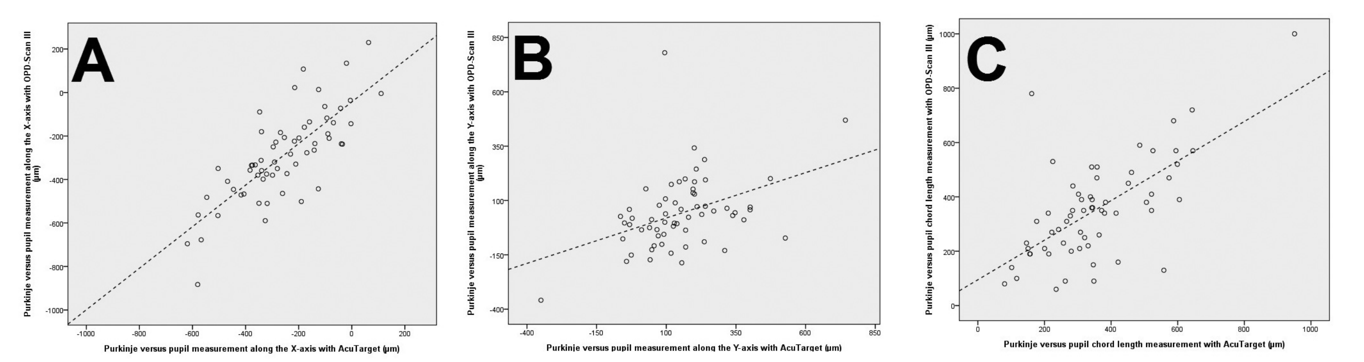

Figure 3. Comparison between data obtained with the AcuTarget (SensoMotoric Instruments, Teltow, Germany) and OPD-Scan III (NIDEK, Inc., Fremont, CA). (A) Purkinje-versus-pupil measurements along the x-axis. (B) Purkinje-versus-pupil measurements along the y-axis. (C) Purkinje-versus-pupil chord length measurements.

DISCUSSION

A reliable device provides low variations between repeated measurements. In this study, we found that the repeatability of the AcuTarget measurements was good (with intraclass correlation coefficients ranging from 0.773 to 0.780). Therefore, the AcuTarget is a reliable device and a single measurement appears to be sufficient.

The OPD-Scan III has been compared to other aberrometers and is repeatable for second-order root mean square (intraclass correlation coefficient: 0.88), but not for higher-order aberrations.[11]

Furthermore, when using an ophthalmic diagnostic device, a quick examination means more comfort for the patient and examiner. No statistically significant difference was found when comparing AcuTarget readings (which correspond to the best of the five acquisitions necessary to perform a measurement) to the mean of the first three acquisitions. This result suggests that only three acquisitions may be sufficient, which would be faster and less unpleasant for patients.

The AcuTarget and OPD-Scan III operate similarly: patients look at a central fixation light and pictures of their eyes are taken. The systems then calculate the distance between the center of the pupil and the vertex. In this study, this distance was 357.01 ± 164.58 µm with the AcuTarget and 352.79 ± 183.39 µm with the OPD-Scan III, which is comparable to values previously reported.[4] Purkinje-versus-pupil measurements along the x-axis and chord length were not statistically different between the two systems and were strongly correlated. Conversely, a statistically significant difference was observed between the two systems for measurements of Purkinje-versus-pupil along the y-axis. Thus, despite operating similarly, results obtained with the two systems are not fully comparable. Acquisitions with the OPD-Scan III and AcuTarget were performed consecutively under mesopic conditions in two adjacent rooms, in which illuminance was similar but not identical. Thus, a difference in pupil size may explain the differences observed in the results along the Y-axis. Moreover, when using the OPD-Scan III, the

TABLE 3
Comparison Between the Mean of the First Three Acquisitions and the Best Acquisition Obtained With the AcuTarget (BA – FTA)

	Difference of Mean		Pearson Correlation		95% LoA	
Parameter	**Δ ± SD (μm)**	***P***	**r**	***P*[a]**	**Lower (μm)**	**Upper (μm)**
Measure 1						
Purkinje-versus-pupil (x-axis)	8.62 ± 46.29	.147	0.971	< .001	-82.11	99.37
Purkinje versus pupil (y-axis)	-8.74 ± 35.52	.057	0.981	< .001	-78.37	60.88
Purkinje-versus-pupil (chord length)	-12.20 ± 43.12	.030	0.967	< .001	-96.74	72.33
Measure 2						
Purkinje-versus-pupil (x-axis)	-3.39 ± 40.22	.508	0.973	< .001	-82.23	75.44
Purkinje-versus-pupil (Y-axis)	3.25 ± 44.02	.562	0.971	< .001	-83.02	89.54
Purkinje-versus-pupil (chord length)	-5.10 ± 35.96	.268	0.979	< .001	-75.59	80.65
Measure 3						
Purkinje-versus-pupil (x-axis)	7.18 ± 44.81	.212	0.972	< .001	-95.02	80.65
Purkinje-versus-pupil (Y-axis)	-7.02 ± 39.28	.164	0.973	< .001	-84.03	69.99
Purkinje-versus-pupil (chord length)	-6.53 ± 34.32	.139	0.984	< .001	-73.82	60.75

LoA = limits of agreement; Δ = change; SD = standard deviation
[a]Two-tailed. A calculated P value of less than .0035 (using Bonferroni method) was considered statistically significant.

patient target is at optical infinity, whereas the fixation target is located at a finite optical distance with the AcuTarget. Reflection of a light source by the anterior surface of the cornea creates a virtual image behind the cornea, also known as the first Purkinje-Sanson image. Determining the location of the corneal light reflex is instrument dependent and simulations have shown that the location may change preoperatively to postoperatively.[12] As explained by Applegate et al., if the fixation target is located at a finite optical distance along the measurement axis, the chief ray is not necessarily parallel to the vertex normal. In this case, to maintain fixation, the eye must rotate and pupil decentration from the vertex normal is a combination of translation and rotation errors.[13] This may also explain the differences observed between the two systems.

A corneal refractive procedure (eg, laser photoablation or corneal inlays) should ideally be centered on the visual axis.[4] However, the visual axis is a theoretical axis and is not identifiable in clinical practice. Nevertheless, it is thought to cross the corneal plane between the vertex and pupillary center projection. It has been debated whether to use the entrance pupil center or corneal vertex as the ideal reference for ablation centration.[13-15] The corneal light reflex has been described as the basis of centration techniques. A previous study showed that, in myopic eyes with moderate to large pupillary offset, corneal vertex-centered LASIK performed better than pupil-centered treatments in terms of induced ocular aberrations and asphericity.[7] In a recent study, Reinstein et al. showed that outcomes of high hyperopic LASIK were not worse for eyes where ablation was centered more than 0.55 mm from the entrance pupil (as determined by coaxially sighted corneal light reflex in eyes with large angle kappa).[16] In corneal excimer laser surgery, the prevailing method for centration is to use the center of the entrance pupil, which corresponds to the line of sight when the surgeon and patient are fixing coaxially. Currently, small aperture corneal inlays are centered on the corneal vertex (which is close to the line of sight).[17,18] However, optical modeling shows that this technique is not optimum for eyes with preexisting astigmatism if it is not corrected to less than 1.00 D. In these eyes, the optimum location for the center of the pinhole may be too far from the corneal reflex.[19]

This study has limitations. First, measurement conditions were close for the two systems, but not identical, which may have led to minor differences in pupil size. Second, we studied pupil size and its relation to axes only in mesopic conditions (static). Pupil analysis in dynamic conditions allows a better understanding of surgery outcomes.

Although controversies about where to center refractive procedures exist, it is important to measure corneal landmarks in a repeatable way. The AcuTarget allows measuring the position of a small aperture inlay in comparison to the center of the pupil and the first Purkinje reflex. This may help in better analyzing the importance of refractive surgery centration in relation to visual acuity and visual symptoms. Measurements provided by the AcuTarget have a good repeatability and are close to those obtained with the OPD-Scan III. Future studies are needed to analyze the relation between the small aperture corneal inlay position and objective and subjective results.

AUTHOR CONTRIBUTIONS

Conception and design (AS, DG, EG); data collection (DG, EG); analysis and interpretation of data (AS, DG, EG); writing the manuscript (EG); critical revision of the manuscript (AS, DG); statistical expertise (AS, EG); supervision (DG)

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